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Use of genetic resources from Jerusalem artichoke collection of N. Vavilov Institute in breeding for bioenergy and health security

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Abstract. The VIR Collection contains 313 varieties and hybrids of Jerusalem artichoke *Heliantus tuberosus* L. The material originated from several countries of America and Europe represents a potential source of valuable traits for breeding, including yield and precocity. Clones of 70 varieties and hybrids of Jerusalem artichoke from 11 countries were evaluated for yield and precocity. The selection of valuable for breeding accessions was carried out. As result of five years screening new perspective genetic sources of valuable commercial traits for breeding were singled out.

Key words: Jerusalem artichoke, genetic resources, varieties, evaluation, yield

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus* L), which originates from the North Central part of the USA, is a perennial that is grown as an annual crop. *H. tuberosus* is distinguished by its large tubers, which have been selected for their food value. Both above- and belowground parts of J. artichoke are utilizable for various applications. For instance, tops for biomass and animal feed and tubers as a feedstock for food and non-food chemical production. All plant parts can potentially be improved to enhance their commercial value. A great deal of morphological variation has been noted in J. artichoke, despite being a crop that has undergone relatively little systematic selection, suggesting that genetic improvement is possible. Tubers, for instance, vary in colour, shape, size, and surface topography (Kays & Nottingham, 2008).

J. artichoke, as a species is highly competitive, quickly shading the soil surface and creating a zone of captured resources, thereby repressing the growth of most other species. Tubers and tops of this crop have a universal value. The tubers of J. artichoke, containing up to 20% of inulin and unique on equation vitamin-mineral complex, are valuable foodstuff with high treatment and prophylactic potential (Baker et al., 1990). Inulin is the storage carbohydrate of J. artichoke, whereas starch is the storage carbohydrate in the majority of plants. Only a small number of crops accumulate inulin in amounts sufficient for cost-effective extraction. Chicory (*Cichorium intybus* L.) and J. artichoke are the most important inulin-storing species (Meijer et al 1993; Kays & Nottingham, 2008;).

Plant-derived inulin can be processed and modified to serve as a feedstock for numerous industrial applications (Parameswaran, 1995). The demand for inulin is growing, particularly within the food industry.

Declining fossil fuel reserves and the need to alleviate the worst consequences of global climate change has stimulated unprecedented interest in alternative fuels and energy sources, including biofuels. J. artichoke produces large amounts of biomass, is fast growing, needs relatively few inputs in terms of pesticides, fertilizer, and water, and can be grown on marginal land. It is therefore a potentially useful crop for the production of biofuel, and in particular bioethanol (Gunnarson et al, 1985; Canadian Forestry Service, 2006). J. artichoke tops (fresh or ensiled) also have potential for the production of biogas (methane) (Tuck et al., 2006).

This interesting and useful crop with the beautiful name “ground-pear”, due to the high ecological plasticity, and thus high efficiency as valuable dietary product, is very attractive to cultivation. It is successfully cultivated in various areas of Russia, especially in the south (Krasnodar region), as well as in Georgia, Ukraine, Byelorussia and Moldova. In Hungary and Poland J. artichoke is widely cultivated for forage purposes. It is also very popular and occupies large areas in France, Sweden, Norway, Canada, USA, and England (Zubr, 1988). J. artichoke is also used as initial material in breeding of sunflower for resistance to diseases and pests.

Structure of top part of J. artichoke is very similar to the related crop – sunflower. Stem is erect, with many leaves. Depending on a variety and conditions of growth the height of stems varies from 1 up to 4 and even 5 meters. The number of branches on the main stems of different varieties varies from 14 up to 30. The elevated parts (tops) of J. artichoke (plants maximal height and weight) are valuable, because biochemical content has not lower value, than tubers.

The character of compactness of tubers depends on length of stolons: from short – to compact friable and sprawling type of tubers (Pashko, 1973). Value of a variety is characterized by parameters as compactness of tubers, their maximal number, and the perfect shape (the minimal index of tuber shape). For breeding an increased tuber yield is the primary selection trait. Yield is determined by genetics, in combination with environmental, climatic, and geographic factors. For instance, high-yielding cultivars may only be highly productive in regions with the photoperiod and temperature conditions under which the cultivar was selected. High tuber yields are desirable for high productivity of inulin and fructose (Fernandez et al., 1988; Sawicka & Michaek, 2005; Kays & Nottingham, 2008;)

In Russian Federation, demand for new varieties of J. artichoke has increased search of a new initial material for breeding. The following aims (precocity, high yield, suitability for production of fructose, inulin, ethanol, medical products, biologically active additives and forage) are very important (Pashko, 1974). Therefore, research on genetic resources of this crop has increased in the N. Vavilov Institute of Plant Industry.

MATERIALS AND METHODS

VIR's J. artichoke collection consists of 313 varieties and hybrids, introduced from 24 countries. 70 samples of J. artichoke cultivars and hybrids, originated from 11 countries were involved in studying. Some of them were created at the Majcop research station. Research on maintenance and studying of the collection accessions was carried out by methods of the VIR (Pashko, 1987; 1989). J. artichoke genotypes were grown and studied in the experimental field of the Majkop Research station of the N. Vavilov Institute of Plant Industry during 2005–2009; plot size for each variety was 5.0 m^2. Plots were arranged in a random design with three replications.

Growing conditions. Soil and climatic conditions were optimal for growth and high-grade development of J. artichoke. Soil type of the experimental field was black hard loamy, it's density varied from 1.15 up to 1.6 g cm^3. The density of a dure phase of ground was 2.60–2.70 g cm^3. The full moisture capacity in arable horizon was 35–55%. The organic matter of soil was 18–27 g kg^{-1}, pH was 6.3–6.4, available P 65–90 mg kg^{-1} and K 115–130 mg kg^{-1}. Fertilizers: N 70–75, P 52–85, K 50–100 kg ha^{-1} was used. The annual course of temperature had strongly pronounced character. The non-frost period was about 200 days, the length of the vegetative period varied from 140 to 150 days. The hydrothermal index during the vegetation of J. artichoke was equal to the average 1.7–1.8 (Zhukov & Marchenko, 1973).

Processing of soil included: ploughing; spring cultivation with harrowing. The tubers were planted in the furrows. The planting material was selected on uniformity concerning the size and forms. Average weight of tubers – 30–50 g; the tuber shape was evaluated corresponding to variety type: short – pear-shaped, pear-shaped or spindle-shaped; tuber skin colour: white, light brown, pink, red or red-violet.

Terms of planting: 1st year of studying – April, 23; 2nd year – April, 13; 3rd year – May, 04; 4 year – April, 24. The layout of planting 0.7×0.7 m was used. The growth area for one plant was 0.5 m^2. Depth of planting – 8–10 cm. Two times furrowing was carried out in May. Phenological observations were carried out each 3 days: shoots (the beginning and maximum), bud creations, flowering (the beginning and maximum), end of vegetation. The account of yield of belowground parts and tuber weight was carried out in three terms of harvesting: September 15 and October 15 – tops (green haulm) weight and tubers; November 15 – tuber weight. From every plot 3 plants were evaluated (each plant separately). The green tops were cut off by secatours at the level of 10 cm above surface of soil and weighed. The account of yield of tubers included: number and weight of tubers, average weight and size of one tuber. The degree of compactness of tubers was evaluated by following scale: compact – 5–15 cm, friable – 16–25 cm, sprawling – 26–40 cm, very sprawling – more than 40 cm (Pashko, 1973).

RESULTS AND DISCUSSION

The carried out evaluation has allowed revealing presence of significant differentiation in morphological characteristics. Optimum parameters for breeding are considered the following: pear-shaped forms of tubers; tuber index – from 1.0 up to 2.0; maximal stem and tuber number, positive ratio to stem number. Stem number is partly determined by the size of seed tuber (Barloy, 1984) and is closely related to early canopy development and leaf area index (Cors & Falisse, 1980). Branching type is genetically controlled, although the number of branches is largely regulated by plant density.

As result of evaluation of particular morphologically valuable traits of accessions, which may be recommended for breeding as parental forms, were singled out. Varieties and hybrids, which had the best data during 5-year evaluation, are shown in the tables 1 and 2. The best of these can by recommend for use as an initial material for following breeding.

Table 1. Morphological characteristics of above ground part of plants (tops) and tubers of the singled out J. artichoke accessions (Majkop res. station, 2005–2009).

Variety name	Origin	Tuber shape	Tuber index	Compact ness**	Stem number
		Early varieties			
Skorospelka (St)	Russia	4	1.30	3	3
Kaluzhskii	Russia	4	2.00	2	2.5
36/99 2M-22-29	Russia	4	1.70	2	2
		Mid-early varieties			
Nakhodka	Russia	2	1.80	2	1
Keningsberg 1	Russia	4	2.05	2	1
Keningsberg 2	Russia	1	8.90	1	3.5
Krasnodarskii 1	Russia	4	1.50	2	3
Krasnodarskii 2	Russia	3	1.40	2	1
Hybrid 32	Russia	4	1.85	2	3
NIIZH	Russia	3	1.95	1	1.5
Seedling 4	Russia	4	1.45	1	1.5
Seedling 32	Russia	4	1.55	2	3
Seedling 53	Russia	4	1.65	2	1
Interes 21	Russia	4	1.55	3	2
		Late varieties			
Lzöllösnya	Hungary	3	1.30	2	1
Matrav	Hungary	3	1.90	2	2
Raposvar	Hungary	4	1.35	2	1
Mosonm	Hungary	4	1.50	2	2
Szirmai	Hungary	4	1.35	2	3.5
Peterburgskii	Russia	3	1.40	2	1
Interes	Russia	3	1.80	3	1

Notifications: * – tuber shape (scale of points: 1–4): 1– spindle-shaped, 2 – oval-oblong, 3 – pear- shaped, 4 – short-pear-shaped
** – tuber index (attitude of length to diameter of tuber)
*** – compactness (scale: 1– 4):1 – very sprawling; 2 – sprawling; 3– friable; 4 – compact

A – tuber shape: 1, Krasnodarskii 2, Peterburgskii, Lzöllösnya, Raposvar and Mosonm;
B – compactness of tubers: Interes, Interes 21;
C – tuber index: Skorospelka, Krasnodarskii 2, Peterburgskii, Lzöllösnya, Szirmai, Raposvar;
D – number of main stems – Keningsberg 2, Hybrid 32, Seedling 32, Szirmai.

The studies show that only some varieties and hybrids may combine a maximum of valuable morphological characteristics, which are only the varieties – Skorospelka, Krasnodarskii 1 and Matrav.

The ideal time interval for a clone to reach maturity depends upon where the crop is grown. In more northern production zones, earlier maturity is highly desirable, as long-season cultivars do not adequately mature before the early frosts. Conversely, if clones reach maturity too early, the length of the growing period is decreased, thereby decreasing the maximum tuber yield that could be achieved (Fernandez et al., 1988; Kays & Nottingham, 2008). Our results of evaluation on precocity allowed singling out varieties, which may be recommended for use in breeding – Kaluzhskii and hybrid 36/99 2M-22-29 (Table 2). They had shown the best data on dynamics of accumulating of tuber and tops weight during the vegetation period.

Growth, yield and compositional characteristics of Jerusalem artichoke have significant influence to biomass production (Stauffer et al., 1981). The size of individual tubers greatly influences harvest efficiency as small tubers generally drop through the lifting chain of the harvester. The same problem occurs during washing after harvesting or peeling prior to processing. Using large tubers increases significantly the efficacy of the operation. Large tubers also shrivel less than small ones. (Bogomolov & Petrakova, 2001; Kays & Nottingham, 2008).

As result of evaluation of separate elements of yield the following varieties and hybrids were singled out:
A) top yield – Peterburgskii, Seedling 32, Seedling 35, Seedling 53,
Matrav, Raposvar, Mosonm, Szirmai
B) tuber yield: Nakhodka, Krasnodarskii 1, Krasnodarskii 2, Seedling 4, Seedling 53, Interes 21 – among middle varieties
Matrav, Peterburgskii and Farmosi – among late varieties
C) tuber maximal weight – hybrid 36/99 2M-22-29 – among early varieties
Krasnodarskii 1, Krasnodarskii2, Hybrid, Seedling 53 – among middle varieties
Raposvar, Peterburgskii, Interes and Seedling 35 – among late varieties

Table 2. The yield of tops and tubers of the singled out J. artichoke varieties and hybrids (Maikop res. station, 2005–2009).

Name of variety, hybrid	Origin	Average yield of tops, kg Sept. 15	Average tuber yield of one plant, kg Oct. 15	Average weight of one tuber, g Oct.15	Average tuber yield of one plant, kg Nov. 15	Average weight of one tuber, g, Nov.15
Early varieties						
Skorospelka (St)	Russia	0.25	0.79	18.95	1.16	29.93
Kaluzhskii	Russia	0.31	0.95	17.25	1.16	27.23
36/99 2M-22-29	Russia	0.45	0.76	26.78	1.15	42.17
Mid-early varieties						
Nakhodka	Russia	0.61	1.42	19.08	1.74	24.15
Keningsberg 1	Russia	0.65	1.37	16.63	1.71	17.35
Keningsberg 2	Russia	0.60	0.36	8.25	0.63	14.70
Krasnodarskii 1	Russia	0.63	1.65	20.08	2.08	27.40
Krasnodarskii 2	Russia	0.60	1.45	21.05	2.05	27.63
Hybrid 32	Russia	0.48	1.04	18.58	1.50	27.23
NIIZH	Russia	0.62	1.11	16.35	1.40	26.25
Seedling 4	Russia	0.61	1.57	21.88	2.08	27.28
Seedling 32	Russia	0.72	1.01	11.60	1.53	23.00
Seedling 53	Russia	0.74	1.43	25.10	1.81	33,28
Interes 21	Russia	0.55	1.39	21.03	1.94	25.40
Late varieties						
Lzöllösnya	Hungary	0.53	0.65	12.60	1.21	24.40
Matrav	Hungary	1.10	1.29	20,75	2.19	27.73
Raposvar	Hungary	0.72	0.88	15.33	1.73	36.18
Mosonm	Hungary	0.85	0.74	13,58	1.26	29.43
Szirmai	Hungary	0.88	1.03	12.88	1.56	24.53
Peterburgskii	Russia	0.74	1.24	26.65	2.02	42.13
Interes	Russia	0.65	1.54	33.30	1.86	44.33
Seedling 35	Russia	1.00	1.16	23.50	1.82	41.13
Farmosi	Hungary	0.87	1.09	13.90	1.89	27.08

CONCLUSIONS

The the result of complex study of collection accessions for morphological characters and commercial traits valuable accessions, combining few valuable traits, representing interest for breeding were singled out. As sources of such traits may be mentioned the varieties Krasnodarskii 1, Krasnodarskii 2, Peterburgskii, Interes, Interes 21, Matrav, Raposvar, Hybrid 32, Seedling 32.

The variety Kaluzhskii and hybrid 36/99 2M-22-29 are both recommended for use in breeding for precocity.

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